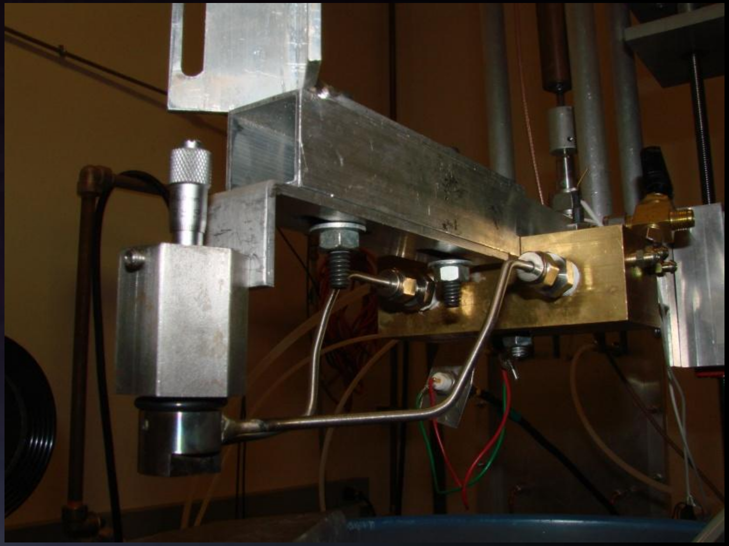
Independent Dynamic Actuation of Spray Parameters with the SARA Gen II Nozzle



Synchronously
Actuated
Response
Atomizer

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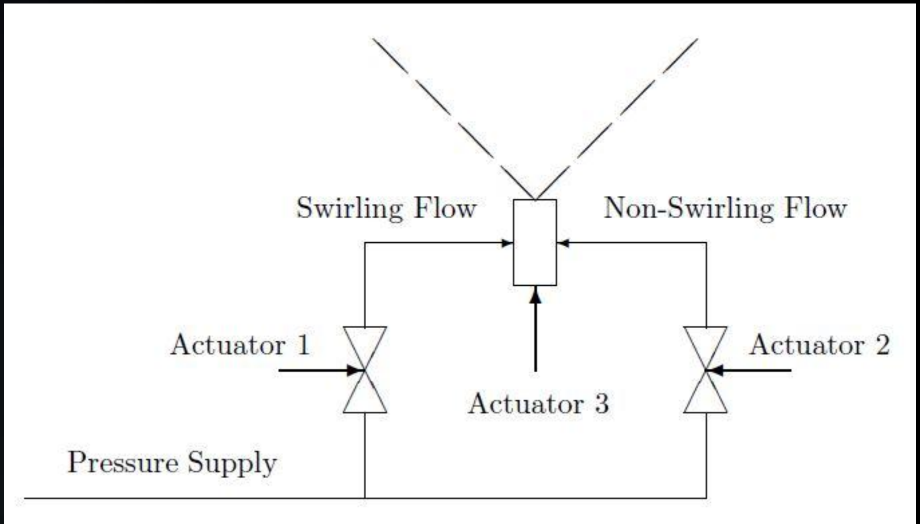
Synchronously Actuated Response Atomizer

Objective: To develop and demonstrate a nozzle capable of independently and dynamically actuating the liquid mass flow rate, angle, and droplet diameter of its spray, at frequencies up to 200 Hz.

Designed a nozzle capable of dynamically altering:

- Cone Angle
- Droplet Size (SMD)
- Mass Flow Rate



Piezoelectric actuators or manual valves provide the actuation

The Dependency of Mass Flow Rate and Cone Angle to the Actuators' Positions were Modeled

Each valve orifice is described by $C_i(x_i)$ Where x_i is actuator i 's position

Mass Flow Rate

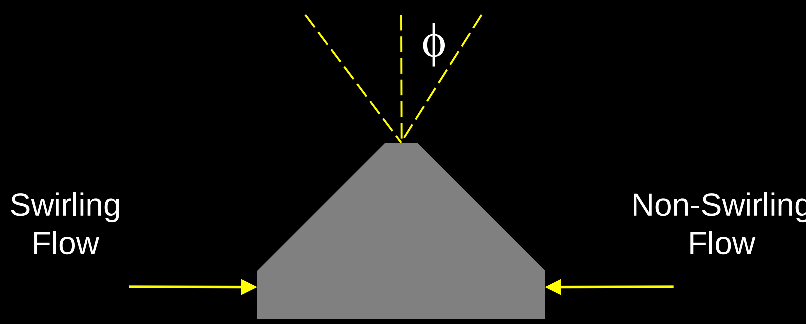
$$\dot{m} = C(\vec{x})\sqrt{\Delta P_s}$$

$$C(\vec{x}) = \left\{\left[C_1(x_1) + C_2(x_2)\right]^{-2} + C_3(x_3)^{-2}\right\}^{-1/2}$$

Cone Angle

$$\frac{\beta_2}{\beta_3}\frac{\hat{R}_2}{\hat{R}_3}\frac{A_3}{A_2}{X_2}^2 = \tan\phi$$

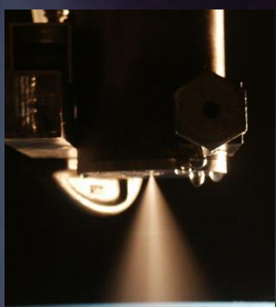
$$X_2 = \frac{\dot{m}_2}{\dot{m}_1 + \dot{m}_2} = \frac{C_2(x_2)}{C_1(x_1) + C_2(x_2)}$$

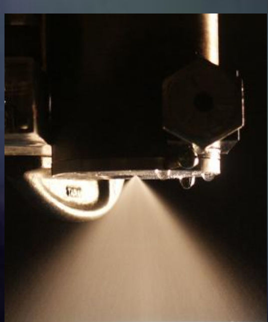


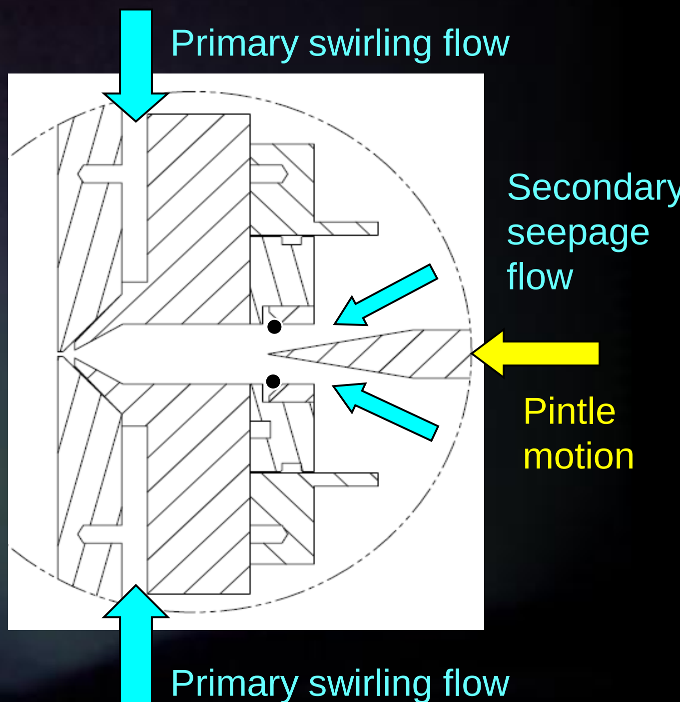
Generation I Success with Cone Angle and Flow Rate Actuation

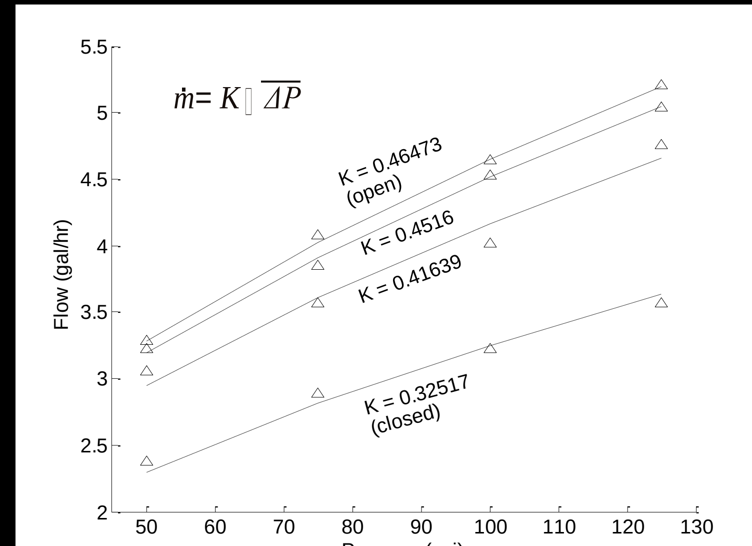
Concentric cones reduce the swirl chamber size.

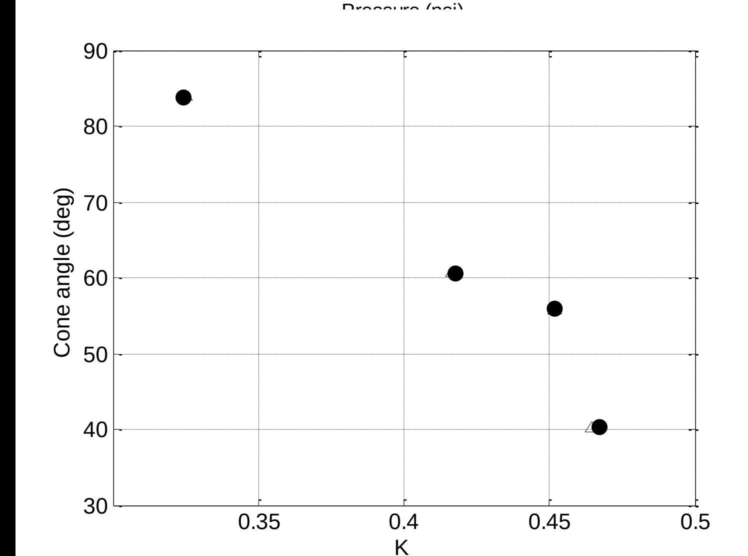
Non-swirling seepage flow allows control over the cone angle











The Sauter-Mean-Diameter is also Independently Controlled via Valve Actuation

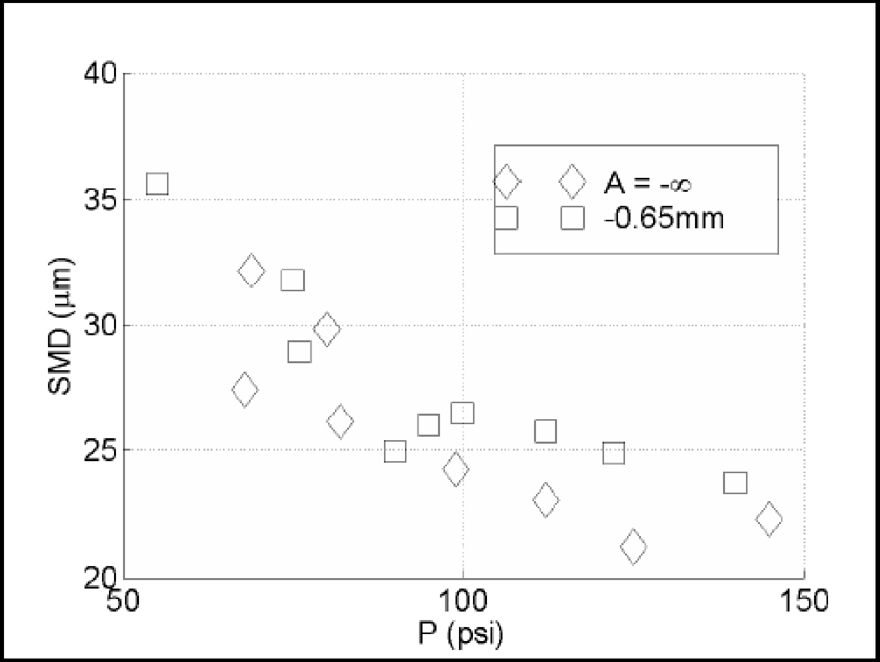
$$SMD \approx \frac{\sum_i {D_i}^3}{\sum_i {D_i}^2}$$

The SMD is a statistical quantity used to characterize droplets in a spray

SMD is dependent on valve position and source pressure

$$SMD = \frac{K}{(\Delta P_3)^n}$$

$$\Delta P_3 = \frac{\dot{m}^2}{{C_3}^2} = \Delta P_s \left[\frac{{C_3}^2}{(C_1 + C_2)^2} + 1 \right]^{-1}$$



The Jacobian Shows that the Three Spray Characteristics can be Independently Actuated

$$\Delta\vec{Z} = \mathbf{J} \cdot \Delta\vec{C}$$

$$\mathbf{J} = \left\{ \begin{array}{ccc} a/{C_{12}}^3 & a{C_{12}}^3 & a/{C_3}^3 \\ -b/C_{12} & -b/C_{12} & b/C_3 \\ -c/C_{12} & -c/C_{12} + c/C_2 & 0 \end{array} \right\}$$

$$a = \frac{\dot{m}}{{C_{12}}^{-2} + {C_3}^{-2}}$$

$$b = 2\ SMD\ \frac{n}{{C_3}^2/{C_{12}}^2 + 1}$$

$$c = 2\phi$$

By measuring the SMD, Flow Rate, ΔP_s ,and Cone Angle the Jacobian can be measured and linear independency proven

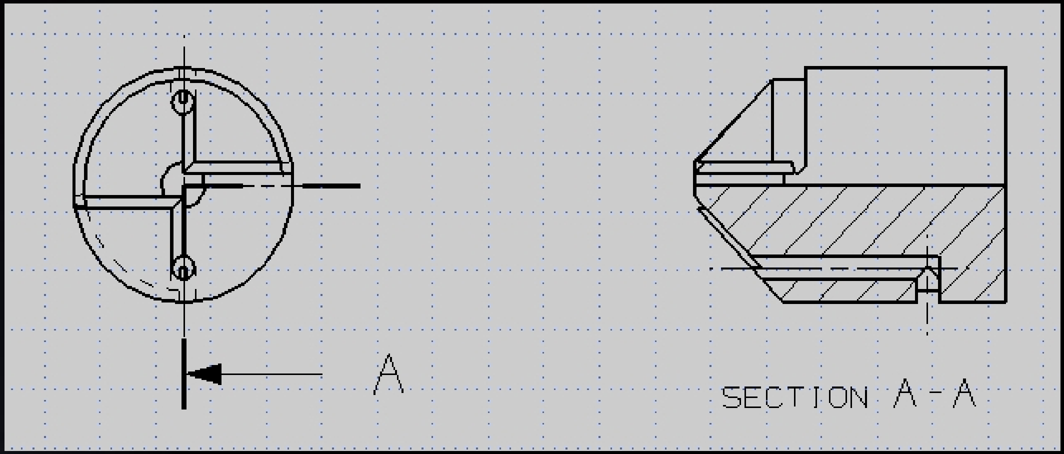
SARA Gen II will Allow us to Measure the Jacobian Dynamically and at Different Operating Conditions

Retained the swirl geometry

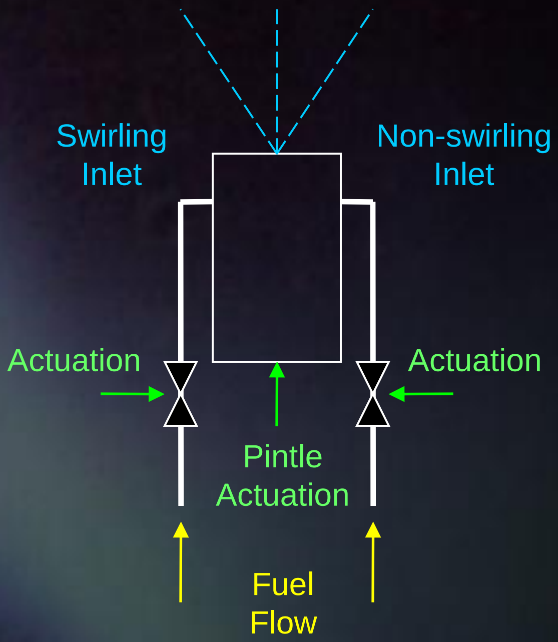
Retained the pintle hole

Added a new non-swirling bypass inlet

Actuate both swirling and non-swirling paths using existing technology

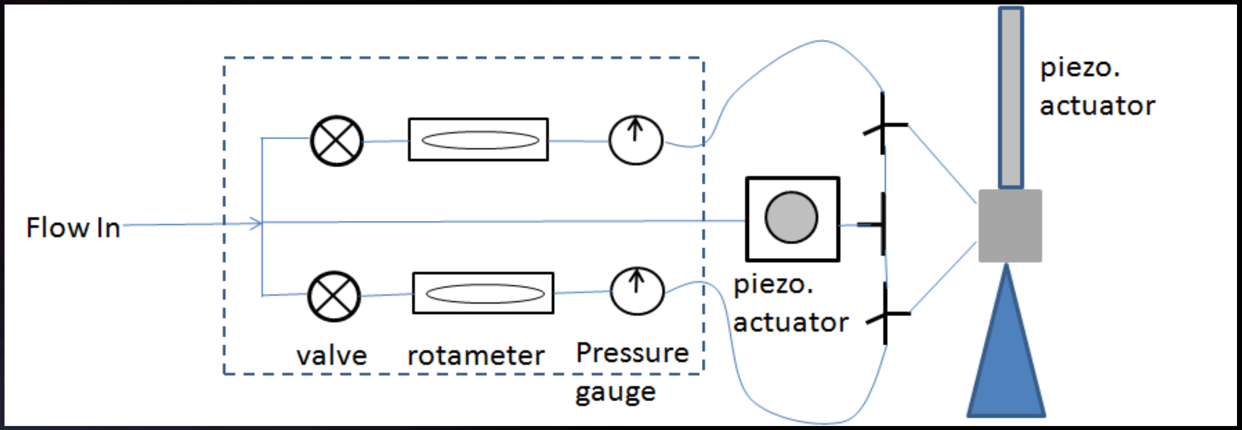


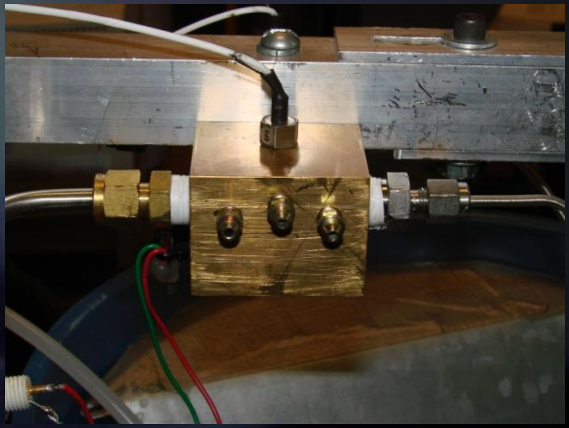
Gen II Design Features Continued



- Cone angle and pressure controls are external
- All parts are smaller and lighter
- Fewer sealed interfaces and less alignment assemblage means drastically reduced friction
- Reduced friction will relax the demands on dynamic tuning
- Self-centering swirl body will align the pintle with a journal bearing

Gen II Testing will Incorporate Dynamic Actuation and Measurement



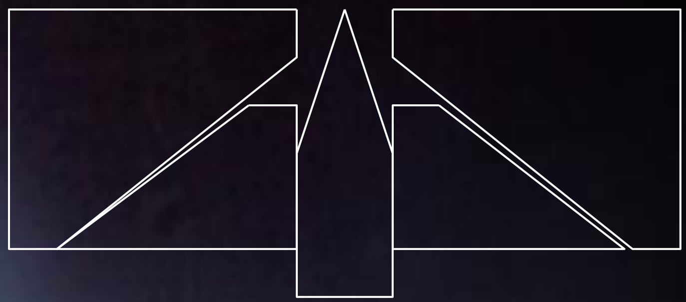


The Twin Block is the Hub of Dynamic Measurements

-Dynamic pressure measurements use "Entran EPX-V01" Sensors

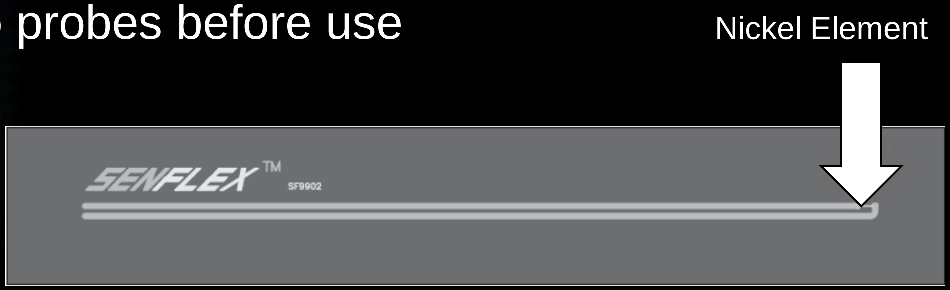
-Dynamic flow rate measurements use Tao Systems "Senflex" hot film probes

Useful Insight has been Gained from Challenges in Nozzle Machining and Hot-Film Probe Use

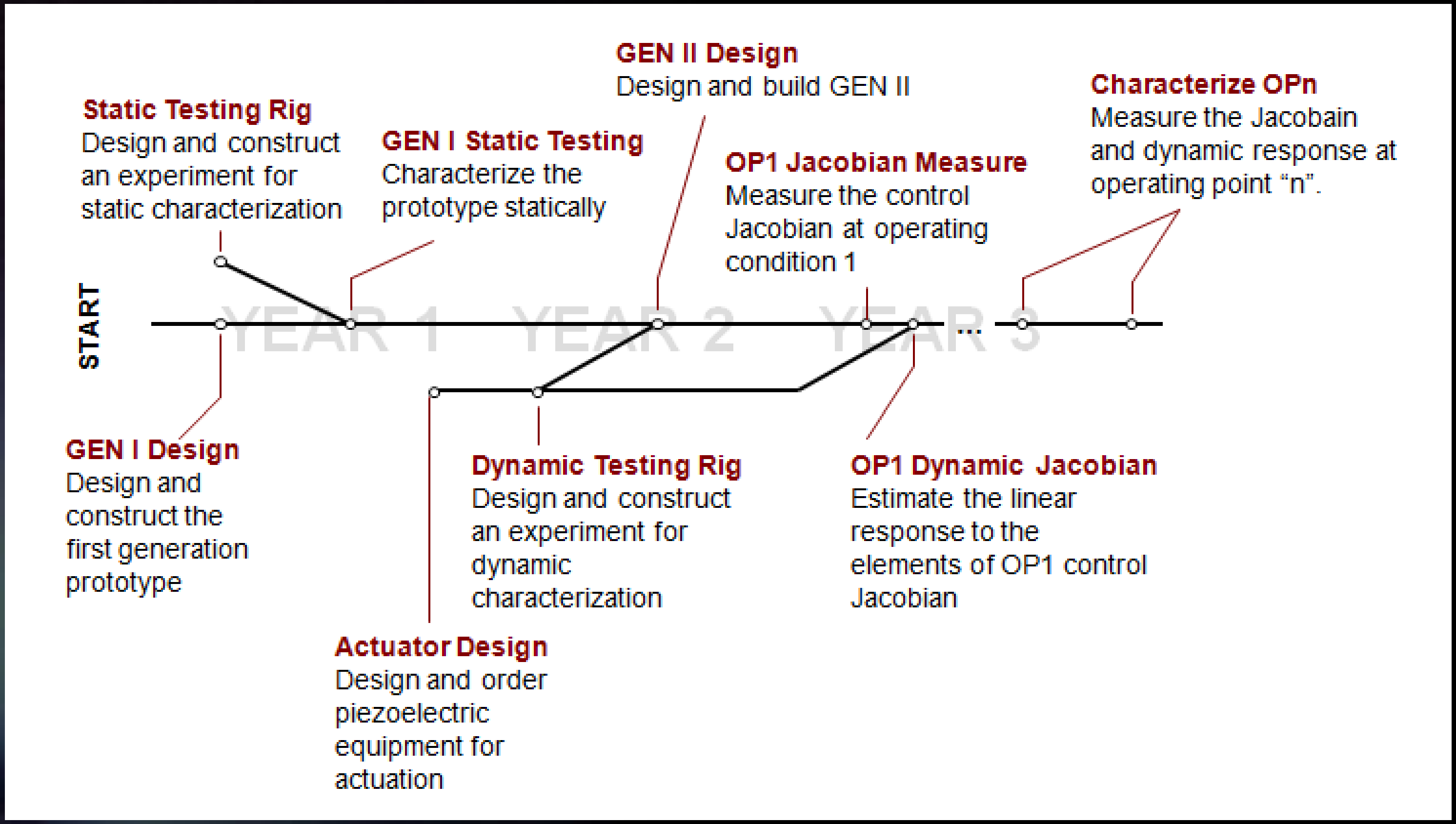


The Nozzle is very sensitive to
- Machining tolerances
- Channel position
- Symmetry
- Damage
- Pintle and swirl-body alignment

Hot Film sheets need to be mounted to probes before use
Special attention needs to be paid to
- Mounting
- Orientation of the probe in flow
- Annealing the sensor
- Calibration



Timeline and Progress
Currently finishing Year 2



Thank you for your time

Questions and Comments